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DYNAMICS OF SUSPENDED SEDIMENT PLUMES IN LAKE ONTARIO

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Abstract

Enhancement of ERTS-1 imagery using the Stanford Research Institute video console yielded excellent quality 35-mm color slides and prints of several prominent turbidity plumes in Lake Ontario. Moreover, the console's plotting capabilities were employed to sketch the shape and areal extent of each large turbidity feature along the lake's south shore. Selected ERTS frames of the Welland Canal and Genesee River plumes will be used to develop time-lapse sequences showing the impact of wind stress on each plume.

Unusually high lake levels during the spring resulted in extensive beach erosion along the entire Lake Ontario shoreline. The resulting high concentrations of suspended matter generated highly turbid (up to 420 JTU) nearshore conditions that appeared milky white in the imagery obtained April 12 and 29th, 1973.

During the shipping season, both the Welland Canal and a diversion channel at Port Dalhousie, Ontario, produced readily identifiable turbidity plumes in Lake Ontario. However, in the winter neither plume was visible in the ERTS imagery suggesting sharply lower sediment discharge into Lake Ontario from these sources.

Type II Progress Report
ERTS-1

a. DYNAMICS OF SUSPENDED SEDIMENT IN LAKE ONTARIO

ERTS-1 Proposal No.: 342-4D

b. GSFC ID No.: IN 058

c. Statement and explanation of any problems that are impeding the progress of the investigation:

None.

d. Discussion of the accomplishments during the reporting period and those for the next reporting period.

A trip to the Stanford Research Institute in Menlo Park, California March 20-22 proved to be quite valuable. By using their Electronic Satellite Image Analysis Console (ESIAC), it was possible to glean information from ERTS-1 70-mm frames that could not be obtained from any other means available to this investigator. For example, color slides of greatly enlarged sections of any ERTS scene of interest were readily obtained from the video console. Best results were obtained by superimposing positive transparencies of bands 5 and 6 on the main video screen and then regulating the resulting color combinations to emphasize water (turbidity) features. Excellent 35-mm color slides were obtained using this approach of the following plumes:

Port Dalhousie Harbor
Welland Canal
Genesee River
Oswego River.

Additionally, several examples of shore erosion were detected, especially in frame 1137-15355-5. The areal extent and shape of each plume was then obtained using ESIAC's special plotting capability.

A time-lapse sequence of the Welland Canal and the Genesee River plumes will be made. Such a sequence requires a minimum of 10-12 frames of a particular turbidity feature. We were successful in obtaining 3 or 4 useable frames of each of these plumes from the ERTS imagery available to us at that time. The importance of a time-lapse sequence is its to show the dynamic changes in a plume resulting from seasonal and short-term meteorologic and hydrologic variations.

Ground truth in the form of near surface measurements of turbidity, water temperature, and suspended sediment were obtained along the south shore of Lake Ontario February 15, 16, April 10-12, May 15-17. Additionally, ground-level photographs were taken and wind speed and direction, sky cover, and sea state observations were made at each of about 25 measurement sites.

Field trips to the project site will be made July 9-12, 1973, August 5-7, 1973, and during October 1973.

e. Discussion of significant scientific results and their relationship to practical applications or operational problems including estimates of the cost benefits of any significant results.

The ERTS satellite imagery shows that the Welland Canal and a diversion channel at Port Dalhousie are among the principal sources of suspended matter entering Lake Ontario during the shipping season. By way of illustration, the turbidity plumes from both Port Dalhousie harbor and the Welland Canal are clearly shown in figure 1. This photograph was obtained from the Stanford Research Institute's ESIAC console which combined bands 5 and 6 on a single video screen. Both plumes were visible on all clear-sky imagery obtained during the shipping season. The turbid waters are the result of oil spillage, ship and pleasure craft wastes, dredging and the resuspension of fine-grained bottom materials caused by turbulence. By way contrast, neither plume is visible in winter (figure 2).

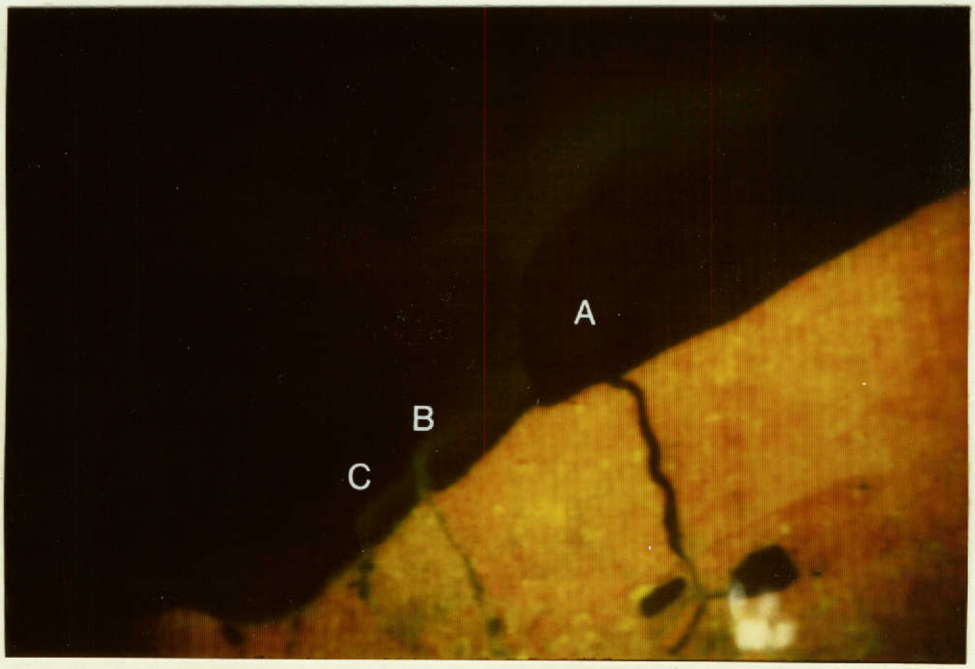

Figure 1.-- Image obtained August 21, 1972, showing the Niagara River plume (A), the Welland Canal plume (B), and the Port Dalhousie Harbor plume (C).

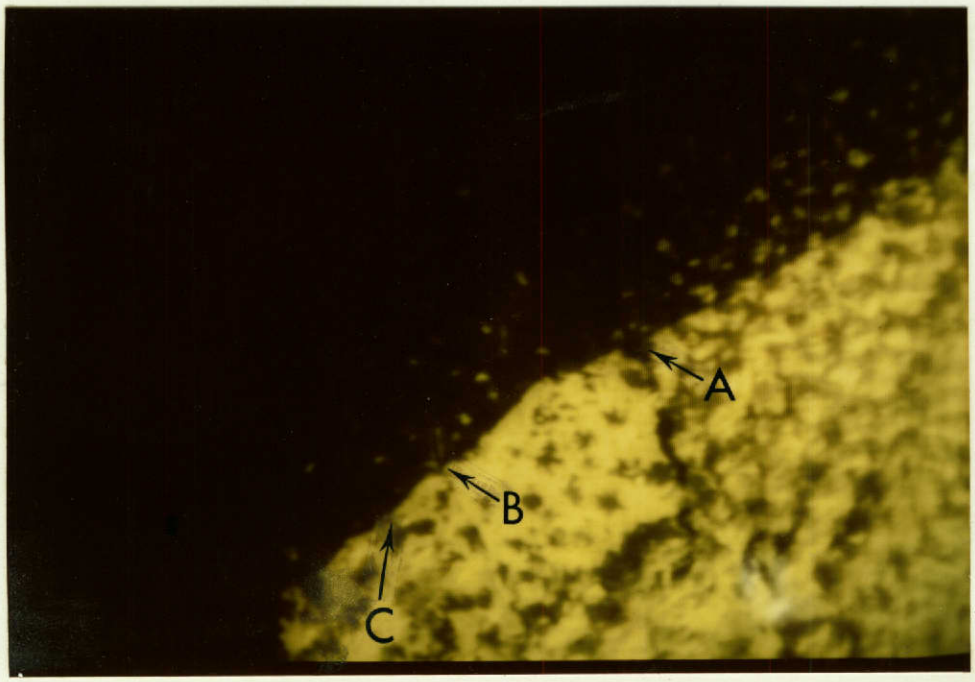

Figure 2.-- Image obtained January 29, 1973, showing the Niagara River (A), the Welland Canal (B), and Port Dalhousie harbor (C).

One unexpected advantage of the turbidity generated by the Welland Canal-Port Dalhousie diversion (average flow: 7,000 cfs) is its value in defining the position of the much less turbid Niagara River plume (average flow: 195,000 cfs). For example, on August 21, 1972, suspended material from the Welland Canal was swept eastward toward the Niagara River (figure 1). Several miles west of the Niagara River mouth, the turbid Welland Canal water encountered westward moving Niagara River water. Unable to continue moving parallel to the shoreline because of the outward spreading Niagara water, the turbid Welland Canal discharge moved along the periphery of the Niagara plume. Unfortunately this fortuitous situation exists only when the Welland Canal-Port Dalhousie plumes are swept eastward toward the Niagara River.

A succession of years with greater-than-normal precipitation has raised water levels in Lake Ontario to near-record proportions. Extensive property damage occurred during the spring in many localities bordering the lake. The combination of high lake levels and strong winds produced sea swells which pounded unprotected nearshore landforms normally "safe" from wave action. The unprotected erodible material is washed into the lake causing highly turbid littoral conditions.

Examples of heavy beach erosion and highly turbid longshore currents are illustrated in the imagery shown in figures 3 and 4 obtained April 12, and 29, 1973, respectively. Turbidity readings of 400 JTU (Jackson Turbidity Units) and 420 JTU were obtained on April 12, 1973, in the narrow band of milky white nearshore waters between the Welland Canal and the Niagara River. These were, by far, the highest turbidity readings obtained in this study to date. Extensive beach erosion is shown in the imagery for April 12 and 29 in all shoreline areas except immediately east of the Niagara River mouth. On both occasions an eastward-trending wave train pounded the southern shore of the lake. However, the northwest orientation of the Niagara River jet in Lake Ontario acted as a barrier to the ambient wave train effectively shielding a portion of the New York State shoreline from erosive wave action.

Figure 3.-- Image obtained April 12, 1973, showing the Niagara River (A), the Niagara River plume (B), and the Welland Canal plume (C).

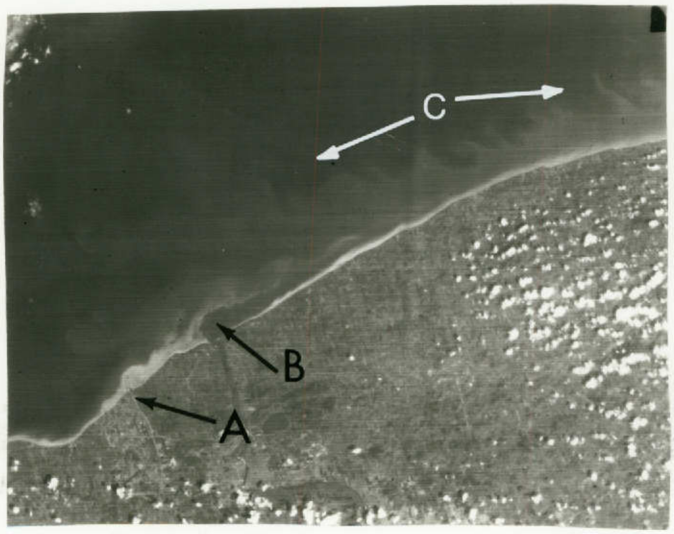

Figure 4.-- Image obtained April 29, 1973, showing the Welland Canal (A), the Niagara River plume (B), and an offshore zone of turbulent mixing (C).

The Port Dalhousie harbor plume is not readily identifiable in the imagery obtained during April 1973. The harbor jetties were overtopped by the abnormally high lake levels thereby forcing rapid mixing of the plume with nearshore currents. The Welland Canal plume is, however, identifiable in figures 3 and 4. On both occasions, the Canal was discharging highly turbid waters into the lake (up to 75 JTU).

Three distinct turbidity zones were depicted off the New York State shoreline on April 29, 1973 (figure 4). These consisted of a very narrow but highly turbid littoral zone, an intermediate zone of much lower turbidity, and a relatively clear water (dark) offshore region. Of special interest is the zone of turbulent mixing between the intermediate and offshore clear-water zones as shown by the band of wave-like turbidity features in figure 4. The dynamic mechanism triggering these "turbidity waves" is unknown, however the amplitude and trend of the waves suggests the existence of large westward moving offshore current as opposed to an apparent eastward moving longshore current.

High turbidity (88 JTU) and suspended sediment concentrations (123 mg/l) along with heavy spring runoff combined to produce an extensive turbidity plume at the mouth of the Genesee River on April 10, 1973 (fig. 5). This river is an important source of suspended material in Lake Ontario and is readily identifiable in ERTS imagery. The Genesee River plume was swept eastward by westerly winds beyond the outlet of Irondequoit Bay. The bay was relatively clear (7.5 JTU) so that it appears dark in the image. ERTS imagery could be used by planners to assess the effectiveness of sediment-control measures. Any significant reduction of river borne sediment would be reflected in the level of brightness of the river at its mouth. As sediment trapping became more effective, the turbidity plume generated by the river would appear darker (less turbid) in the imagery.

Category designation 4D, 5H, 7C

f. A listing of published articles, and for paper, pre-prints, in-house reports, abstracts of talks, that were released during the reporting period:

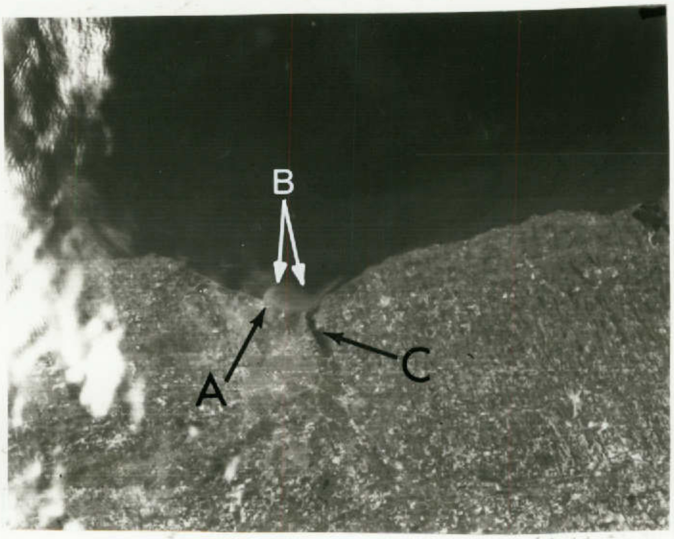

Figure 5.-- Image obtained May 16, 1973, showing the Genesee River (A), the Genesee River plume (B), and Irondequoit Bay (C).

A paper "Remote sensing of turbidity plumes in Lake Ontario" was presented at the NASA ERTS-1 Symposium at New Carrollton, Maryland, on March 6, 1973.

A report "Remote sensing of turbidity plumes in Lake Ontario" will be published in the U.S. Geological Survey's Journal of Research.

g. Recommendation concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system.

The distribution of imagery continues to improve but faster service would be very helpful.

h. A listing by date of any change in standing Order Forms:

None

i. ERTS Image Descriptor forms:

Prepared through May 1973 and transmitted to the Goddard Space Flight Center on July 2, 1973.

j. Listing by date of any changed Data Request forms submitted to Goddard Space Flight Center/NDPF during the reporting period:

None